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A STUDY OF ROCK BEHAVIOUR FOR THE DONKIN-MORIEN ROCK/SUPPORT INTERACTION CONTRACT

M. Bétournay
ROCK MECHANICS LABORATORY

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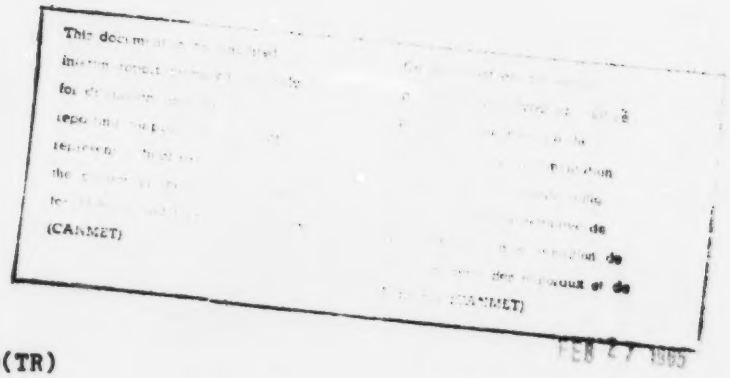

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by

M. Bétournay*

ABSTRACT

From six locations within the access tunnels five geological unit types (Unit I-V) from the Donkin-Morien Site, Nova Scotia, provided the samples used for an extensive testing program. Both compression and tensile tests were performed on sandstones, siltstones, mudstones and gradational types. The sandy-siltstone was found strongest followed by the sandstone, silty-mudstone, mixed siltstone and mudstone. Specimens from gradational units were stronger when the amount of silt was high.

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*Physical Scientist, Mine Evaluation Group, Mining Research Laboratories, CANMET, Energy, Mines and Resources Canada, Ottawa.

ÉTUDE DU COMPORTEMENT DES ROCHES EN VUE DE LA RÉALISATION DU CONTRAT ROCHE/SOUTÈNEMENT AU SITE DONKIN/MORIEN

par

M. Bétournay*

RÉSUMÉ

Dans le cadre d'un programme d'essais exhaustif, cinq unités géologiques (Unités I à V) du site Donkin-Morien, Nouvelle-Écosse, ont fourni des échantillons provenant de six emplacements à l'intérieur des tunnels d'accès. Des essais de résistance à la compression et des essais de traction ont été effectués sur des grès, de l'aleurolite, de la pélite et d'autres échantillons des unités graduelles. L'aleurolite sableuse s'est avérée la plus résistante suivie du grès, des mélanges d'aleurolite et de pélite. Les échantillons provenant des unités graduelles étaient plus résistants quand la teneur en éléments silteux était élevée.

*Chercheur en science physique, Groupe d'évaluation des mines, Laboratoires de recherche minière, CANMET, Énergie, Mines et Ressources Canada, Ottawa.

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INTRODUCTION

To comply with an interactive agreement between the Cape Breton Coal Research Laboratory and the Rock Mechanics Laboratory, a testing program was established to subject several specimens of varying rock types to uniaxial and triaxial compression tests, as well as to Brazilian tensile tests.

The specimens originated from several boreholes of the Donkin-Morien Site, Nova Scotia. The tests were performed within the March to September 1984 time period. The boreholes were drilled in two tunnels at various chainage:

	Coding			
3T1025EA				
3T1025ED	3T	1025	E	A
3T900EB	Tunnel	Chainage	Extensometer Hole	Direction of Hole
3T800EB				
2T1881EA				
2T1420A				

Borehole 2T1420 was used for strata identification.

The purpose of the tests was to quantify the behaviour of the rock units required in connection with the Donkin-Morien Rock/Support Interaction Contract.

The multiple failure state test established by Kovari and Tisa (1) was used to extract triaxial information at various confining pressures. Standard uniaxial tests were also performed. Peak strengths with accompanying strains, modulus of elasticity and residual strength data were the parameters required. Both tests were performed using stiff testing equipment to obtain post failure data. Brazilian type tests were used to acquire tensile strength data.

SPECIMEN DESCRIPTION

The specimens originated from five of the lithological unit types present on site. The following can be used as a general description of these units.

Unit I	Fine to medium-grained sandstone with or without coal
Unit II	Fine sandstone interbedded with siltstone with or without coal
Unit III	Siltstone
Unit IV	Mudstone interbedded with silty laminations
Unit V	Mudstone

The specimens of the same unit type may not be from the same strata as unit types are repeated in several alternating beds.

EXPERIMENTAL SET-UP

A stiff triaxial assembly was used to obtain full uniaxial and triaxial response from rock specimens, pre- and post-failure. The confinement to a Hoek pressure vessel was provided by a confining pressure panel capable of generating up to 205 MPa pressure [Gorski (2)]. A universal compression testing machine provided the vertical load through a hardened steel cylinder load cell, strain gauged to produce micro-strain readings. Disc springs acted as stiffening elements to reduce the total energy imparted to the sample by the compression machine. This, and the operation of a magnetoelectric valve which opens and shuts the hydraulic bypass of the testing machine for faster unloading than manual control unloading, permits the resolution of the rock behaviour in the post failure region. This valve was developed by Mr. F. Kapeller of CANMET. Loading was applied at approximately 3×10^{-3} strain/min for all tests. LVDT's were used in conjunction with applied load to trace out the stress-strain curves and served as a back up for elastic modulus when the strain gauges were operational. The latter were used also to measure Poisson's ratio, and became a more sensitive indicator of failure onset compared to the LVDT's. On one X-Y-Y pen recorder, two curves were drawn; one with the load cell and LVDT signals yielding a stress-strain curve, one with the load cell and confining pressure signals yielding a load versus confining pressure curve. On a second, the load versus sample deformation using strain gauges (when they can be used) both axially and diametrically. Three strain indicators were used to visually monitor the axial, diametric and load cell strains during testing.

SPECIMEN BEHAVIOUR AND RESULTS

Table 1-5 and Fig. 1-6 present the compression and tensile test results for samples from the six chainage locations.

Location 3T1025, Compression Test Results

All five unit types of this location were represented by test specimens.

The sandstones of Unit I displayed little variation in strength, peak or residual, although borehole A has produced samples stronger than those of borehole D. Such similarities are also a characteristic of the values of the moduli of elasticity and strains at peak strength. It is noteworthy that, even under zero confinement, this rock type is controllable in the post peak region, all the way to residual.

Although Unit II shows a small disparity in strength values, it must be pointed out that when a test specimen truely reflects the interbedded nature of this unit, its composite nature probably becomes responsible for premature fracturing of the specimen, e.g. sample 13.77.

The Unit III siltstones also displayed little variation in results, but the presence of fissile layers caused a strength reduction.

Unit IV, interbedded siltstone mudstones, showed by far the largest variation in results. The presence of several fissile planes have affected the behaviour of these specimens.

For Unit V, based on unconfined compressive strength, little variation existed between results. That this rock type is more ductile is shown by the sample's joining of peak and residual limit strength curves, Fig. 6.

Comparatively the tensile strength of these units are:

$$II>I>IV>III,V$$

the deformations from peak strains are:

$$V<I\ ED<I\ EA<IV<III<II$$

for the samples that were gauged, Poisson's ratios are:

$$II,I\ EA<I\ ED$$

Location 3T1025, Brazilian Tensile Test Results

Samples from all of these rock units were tested with the vertical load parallel to fabrics (fissiles, carbonaceous layers) contained on the

circular faces of the specimens. Table 2 displays the results and averages of these tests. Units III - V were tested moist.

Unit I EA specimens, of medium grained sandstone, did not fail along the carbonaceous layers that were occasionally present.

Of the Unit I ED specimens, fine to coarse-grained sandstone, occasionally containing clasts of mudstone, the fine grained specimens displayed higher tensile strength.

Unit II, a fine grained sandstone-siltstone with some interlayered mudstone, displayed the highest variation in results amongst the five units and the highest strength.

Unit III, a muddy siltstone with occasional partially through-going pre-test fissile dicontinuities, failed along fissile planes and by axial load splitting. This unit also displayed the least variation in results.

Unit IV, a siltstone-mudstone with occasional carbonaceous layer, showed that samples with higher silt content have higher strength.

Unit V, a silty mudstone with occasional carbonaceous layer or partially through-going pre-test fissile discontinuity, displayed the lowest strength of all the units.

Comparitively the tensile strength of these units are:

II>I ED>I EA>IV>III>V

This order is the same as that reflected by the compression test results.

Location 3T800 and 3T900

These sandstone samples were drilled parallel to bedding, thereby containing planar fabrics such as bedding or carbonaceous layers along the long axis of the specimens or parallel to axial load. The samples exhibited splitting along the bedding traces. The amount of vertical separation was directly proportional to the resolution of bedding; when the latter was absent, diagonal planar failure took place. The samples with some or much of the specimen incorporating carbonaceous layers were the ultimate examples of this splitting mode. A first (highest) peak of strength occurred reflecting the splitting off of a layer. A second (lower) peak of strength occurred reflecting failure in the remainder of the specimen. Because the diametric

gauges were placed to span the coal-sandstone contact, this splitting forced large deformations upon them. This will explain the unusually high Poisson's ratio for samples 800EB 40.93, 40.84 and 41.02.

The strength of the samples is a clear indication of the presence of vertically-oriented layering. The strongest samples (resembling the Unit I 3T1025EA and ED values) Table 3, were the ones with no apparent bedding, 90.4 ± 6.1 MPa; the sandstone samples with apparent bedding averaged 75.4 ± 10.5 MPa, while the samples with varying amounts of coal layers averaged 62.2 ± 14.6 MPa. The higher Poisson's ratio for specimens with apparent bedding also underlines this.

Location 2T1881EA

The specimens tested were muddy-siltstones failing diagonally rarely along fissile layers; this could be an indication of high amounts of silt. The results show an increase in strength with higher confining pressure and variation in behaviour/expected strength. The samples were tested moist.

Location 2T1420A

The specimens tested were muddy siltstones which failed predominantly in a blocky fashion: this could be an indication of high clay content. There is some variation in the results (specimens tested uniaxially and moist); the average being 55.6 ± 14.2 MPa.

CONCLUSIONS

Certain very clear conclusions about each unit type can be drawn from this testing program. The strongest type is Unit II, a fine sandstone interbedded with siltstone; it does not vary in strength, except when interbedded with mudstone, such as displayed in the tests at location 3T1025. Unit I is the next strongest unit type, also displaying little variation in test results, when planes of weaknesses are not parallel to axial load. In this latter case the strength of the specimens were directly proportional to the degree of weaknesses. Unit IV is the third strongest unit type yet displays high variation in strength. Unit III is fourth and shows little variation in strength.

Unit V, mudstone, shows the lowest strength, and is usually prone to fissile splitting as in the case of Unit III and IV. Observations show that a higher silt content (probably responsible for planar failure development as compared to more fissile splitting) increases the strength of the specimens, such as silty sandstone, silty mudstone.

REFERENCES

1. Kovari, K. and Tisa, A. "Multiple failure state and strain controlled triaxial tests"; Rock Mechanics 7, 17-33; 1975.

2. Gorski, B. "The Design and operation of a stiff triaxial assembly for post failure rock property testing"; Division Report MRP/MRL 82-81(TR); CANMET, Energy, Mines and Resources, Canada; 1982.

Table 1 - Compression test results for specimens from 3T1025

Lith. Unit	Sample No.	L/D	σ_3 (MPa)	σ_{1p} (MPa)	ϵ_p ($\times 10^{-3}$)	σ_r (MPa)	E (GPa)	ν	Remarks
I	EA-6.04	2.26	0	127.2	8.0		17.8/19.7	0.11	
	EA-6.16	2.26	0.35	110.4	7.2	8.5			
			1.03	117.2	7.6	15.1			
			1.72	126.3	8.1	21.9			
			2.41	124.0	8.1	25.0			
			3.10	131.4	9.5	31.0			
			3.79	133.1	8.7	35.3			
			4.48	134.2	8.9	39.8			
			5.17	126.9	8.9	43.2			
	EA-6.25	2.26	0	120.3	7.8	5.7	17.1/18.8	0.11	
	EA-6.33	2.25	0	122.9	8.3	7.1	19.0/19.2	0.09	
	EA-6.44	2.26	0	123.0	8.0		19.8/20.42	0.17	
	EA-6.53	2.27	0.35	106.6	8.1	5.7			
			1.03	112.0	8.5	12.6			
			1.72	108.9	8.5	18.9			
			2.41	104.3	8.7	24.1			
			3.10	107.8	8.9	29.2			
			3.79	112.9	9.1	33.8			
			4.48	110.6	9.3	37.8			
			5.17	111.5	9.3	39.6			
	EA-7.13	2.26	0.35	137.9	7.4	6.2			
			1.03	144.2	7.8	12.8			
			1.72	149.2	8.0	18.7			
			2.41	154.4	8.2	24.4			
			3.10	160.6	8.6	28.4			
			3.79	166.3	9.0	32.9			
			4.48	169.7	9.1	38.0			
			5.17	178.2	10.0	46.5			
	EA-7.21	2.26	0	134.1		5.2	21.6/24.9	0.13	

E values: upper/lower are measured by strain gauge and LVDT, respectively.

p = peak

r = residual

Table 1 - Cont'd

Lith. Unit	Sample No.	L/D	σ_3 (MPa)	σ_{1p} (MPa)	ϵ_p (x10^{-3})	σ_r (MPa)	E (GPa)	ν	Remarks
	ED-14.43	2.25	0	145.1	7.7	43.4	19.0/22.8	0.20	
	ED-15.35	2.26	0	112.8	6.8	5.7	22.7/21.8	0.20	
	ED-16.68	2.26	0.35	81.6	5.0				
			1.03	89.6	5.4				
			1.72	93.6	5.7				
			2.41	99.2	5.9				
			3.10	104.9	6.3				
			3.79	108.3	6.5				
			4.48	111.7	6.7				
			5.17	115.1	6.8				
I	ED-16.85	2.26	0	84.5		5.8	23.4/24.0	0.19	
	ED-18.23	2.26	0	92.4	6.7		21.3/	0.19	
	ED-18.97	2.26	0	99.8	6.5	4.6	21.8/20.5	6.5	
	ED-19.75	2.26	0	101.5	7.1		17.0/18.8	0.15	
	ED-20.51	2.26	0.35	100.4	6.1	11.3			
			1.03	105.5	6.5	19.3			
			1.72	107.7	6.6	25.5			
			2.41	103.8	6.6	29.5			
			3.10	113.9	7.1	29.5			
			3.79	117.4	7.4	36.9			
			4.48	120.2	7.5	40.8			
			5.17	122.5	7.6	43.1			

E values: upper/lower are measured by strain gauge and LVDT, respectively.

Coal layer: 0.5 - 1.0 mm in thickness.

Coal band: <0.5 mm in thickness.

Coal trace: faintly distinguishable outline of coal.

p = peak

r = residual

Table 1 - Cont'd

Lith. Unit	Sample No.	L/D	σ_3 (MPa)	σ_{1p} (MPa)	ϵ_p ($\times 10^{-3}$)	σ_r (MPa)	E (GPa)	ν	Remarks
	EA- 8.47	2.25	0	47.9	10.7	1.7	/6.6		(1)
	EA-10.84	2.25	0	152.8	10.7		18.0/17.7	0.11	
	EA-13.77	2.26	0.35	175.0	11.8				(2)
			1.03	167.1	11.8				
			1.72	169.4	11.9				
			2.41	171.0	12.0				
			3.10	176.0	12.0				
			3.79	165.3	12.1				
			4.48	169.3	12.3				
			5.17	166.5	12.5	56.8			
II	EA-17.39	2.26	0	139.2	9.2	2.8	19.6/19.0	0.16	
	EA-18.36	2.26	0	145.6	8.7		21.9/21.0		
	EA-19.03	2.26	0.35	182.4		17.1			
			1.03	189.8		25.7			
			1.72	197.3		32.8			
			2.41	202.9		38.5			
			2.10	204.7		45.6			
			3.79	205.2		49.9			
	EA-19.56	2.26	0	140.5	8.9		20.3/20.3		
	EA-21.01	2.26	0	101.5	11.6	5.7	15.4/14.0		

E values: upper/lower are measured by strain gauge and LVDT, respectively.

(1) Contained one through going fissile discontinuity; other fissile planes became part of the failure surface. Sample tested moist.

(2) Sandstone with coal and mudstone bands; cracking after 0.35 confinement.

p = peak

r = residual

Table 1 - Cont'd

Lith. Unit	Sample No.	L/D	σ_3 (MPa)	σ_{1p} (MPa)	ε_p ($\times 10^{-3}$)	σ_r (MPa)	E (GPa)	ν	Remarks
	EA-11.92	2.25	0	29.6	8.0	8.5	/4.5		
	EA-12.02	2.14	0	37.3	10.7	2.1	/4.6		
	EA-12.18	2.26	0.35	51.3	19.5				
			1.03	53.8	20.0				
			1.72	53.8	20.2				
			2.41	53.3	20.3				(2)
			3.10	52.1	20.3				
			3.79	53.0	20.4				
			4.48	53.0	20.5				
			5.17	53.8	20.7				
III (3)	EA-12.38	2.14	0	35.4	13.8	2.1	/4.6		(1)
	EA-12.72	2.27	0	37.0	9.8	0.4	/4.8		(1)
	EA-21.58	2.27	0.35	51.3	8.9				
			1.03	50.2	9.2				
			1.72	47.8	9.2				
			2.41	45.5	9.2				
			3.10	44.1	9.2				
			3.79	40.3	9.2				
			4.48	37.6	9.3				
			5.17	37.3	9.3	36.9			
	EA-21.74	2.27	0	39.1	7.9	1.0			
	EA-21.94	2.27	0.35	13.9					
			1.03	19.8					(2)

E values: upper/lower are measured by strain gauge and LVDT, respectively.

(1) Some partially through going fissile discontinuities before test.

(2) Some partially through going fissile discontinuities before test; specimen crumpled.

(3) Samples tested moist.

p = peak

r = residual

Table 1 - Cont'd

Lith. Unit	Sample No.	L/D	σ_3 (MPa)	σ_{1p} (MPa)	ε_p ($\times 10^{-3}$)	σ_r (MPa)	E (GPa)	ν	Remarks
			0.35	34.4	8.4				
			1.03	35.7	8.8				
			1.72	37.3	9.4				
	ED- 5.94	2.27	2.41	38.1	9.6				
			3.10	41.8	10.3				
			3.79	44.5	10.6				
			4.48	45.9	11.1				
			5.17	47.8	.7				
			0.35	46.1	6.7	5.7			
			1.03	51.6	7.8	9.2			
			1.72	52.2	8.0	11.9			
			2.41	46.9	8.1	13.6			
IV (4)	ED- 7.12	2.26	3.10	48.4	8.1	15.7			
			3.79	47.2	8.1	17.2			
			4.48	47.2	8.4	19.1			
			5.17	49.5	8.7	20.1			
	ED- 7.93	2.27	0	33.3	8.4	0.7			(1)
	ED- 8.62	2.27	0	14.7	3.8		/5.0		(2)
			0.35	78.8	5.9	7.9			
			1.03	81.4	6.0	14.7			
			1.72	84.2	6.2	20.1			
			2.41	83.0	6.2	25.0			
	ED- 9.20	2.26	3.10	77.9	6.6	30.0			
			3.79	79.4	6.8	34.0			
			4.48	82.2	6.9	38.3			(2)
			5.17	86.2	7.2	42.8			
	ED-10.57	2.26	0	62.9	6.7	5.1	/10.5		
	ED-12.50	2.27	0	45.5	6.2	1.8	/10.4		
	ED-13.61	2.27	0	34.1	4.0	5.7	/15.0		(3)

E values: upper/lower are measured by strain gauge and LVDT, respectively.

(1) Fissile through going discontinuity (80° to axis) before testing. Many fissile planes became part of the failure surfaces.

(2) Failure plane follows the coal bands (45° to axis); sample failed early by dislocating along coal band (?).

(3) Siltstone.

(4) Samples tested moist.

p = peak

r = residual

Table 1 - Cont'd

Lith. Unit	Sample No.	L/D	σ_3 (MPa)	σ_{1p} (MPa)	ϵ_p ($\times 10^{-3}$)	σ_r (MPa)	E (GPa)	ν	Remarks
	ED- 0.66	2.26	0.35	79.7	3.7	23.5			(1)
	ED- 1.81	2.26	0	37.6	7.4	11.6	/15.0		(1)
	ED- 4.15	2.26	0	30.9	3.5	3.1			(2)
V (4)	ED- 5.30	2.26	0.35			3.8			
			1.03			8.8			
			1.72	45.2	6.0	14.5			
			2.41	46.1	6.0	18.0			
			3.10	46.3	6.6	21.6			
			3.79	46.5	7.0	26.2			
			4.48	47.5	7.2	30.5			
			5.17	49.0	7.6	32.6			
	ED-11.60	2.26	0	36.3	4.4	5.0	/12.0		(3)
	ED-12.05	2.27	0	38.8	5.0	0.5	/8.8		
	ED-21.42	2.26	0.35			7.9			
			1.03	97.2	6.4	17.0			
			1.72	96.9	6.5	23.2			
			2.41	102.0	6.9	29.5			(1)
			3.10	106.8	7.3	36.3			
			3.79	104.5	7.4	41.4			
			4.48	102.6	7.7	47.6			
			5.17	97.0	7.9	48.8			
	ED-22.21	2.26	0	42.2	5.8	11.3			

E values: upper/lower are measured by strain gauge and LVDT, respectively.

(1) Siltstone - mudstone

(2) Siltstone - mudstone with some wavy coal bands

(3) Siltstone

(4) Samples tested moist

p = peak

r = residual

Table 2 - Brazilian tensile test results for specimens from 3T1025

Borehole	Unit	Interval (m)	Tensile strength (MPa)	Borehole	Unit	Interval (m)	Tensile strength (MPa)
EA	I	5.95	9.55	EA	III	11.85	2.77
		6.60	7.61			12.23	3.92
		6.74	9.24			12.27	4.13
		6.82	8.10			12.31	1.92
		6.88	6.20			12.44	2.95
		6.94	5.66			12.58	4.13
		6.97	6.94			21.42	4.91
		7.01	5.63			21.50	4.58
		7.29	6.76			21.83	3.19
		7.37	7.11			22.02	2.27
		$\bar{x}$ = 7.28 ± 1.29				$\bar{x}$ = 3.48 ± 0.95	
ED	I	14.13	8.51	ED	IV	5.88	2.51
		14.51	9.22			7.38	5.13
		15.21	8.48			8.24	4.79
		15.99	7.72			8.91	4.21
		16.32	5.93			10.40	3.52
		16.74	5.71			11.11	6.25
		18.15	7.63			12.23	2.54
		18.87	7.56			12.81	3.15
		19.67	7.72			12.67	2.30
		20.32	7.98			13.10	2.98
		$\bar{x}$ = 7.65 ± 1.04				$\bar{x}$ = 3.74 ± 1.25	
EA	II	8.00	4.70	ED	V	0.19	2.28
		9.26	10.60			1.08	5.35
		10.62	11.91			4.24	1.48
		11.34	11.25			4.50	3.07
		13.25	10.85			5.67	2.47
		13.42	8.15			11.76	4.36
		14.70	6.85			11.99	3.21
		16.53	8.32			21.50	3.42
		17.99	7.90			22.36	5.96
		19.46	9.09				
		$\bar{x}$ = 8.96 ± 2.12				$\bar{x}$ = 3.16 ± 1.51	

p = peak
r = residual

Table 3 - Compression test results for specimens originating from 3T800EB and 3T900EB

Lith. unit	Sample No.	L/D	σ_3 (MPa)	σ_1 (MPa)	ϵ_p	σ_r (MPa)	E (GPa)	ν	Remarks
	800EB 21.05	1.71	0	93.0	6.3	3.5	21.1/20.3	0.23	1
	21.14	1.71	0	85.7	5.1	3.3	21.2/22.2	0.25	1
	21.23	1.72	0	96.5	6.5	6.6	21.3/21.5	0.24	1
	21.40	1.71	0	90.2	6.0	3.3	20.0/20.0	0.24	1
	21.49	1.71	0	91.0	6.4	3.8	20.2/20.3	0.24	1
	21.58	1.71	0	83.1		1.7	24.1/27.5	0.32	1
	30.07	1.71	0	99.5	5.7	3.3	25.3/24.4	0.22	1
	30.16	1.71	0	93.3	5.9	4.6	20.8/20.3	0.18	1
I	30.25	1.72	0	81.1		1.3	20.8/23.8	0.15	1
	38.05	1.71	0	80.1	5.4	3.0	20.0/23.6	0.26	3
	38.13	1.72	0	81.1	5.7	3.1	19.1/18.9	0.27	3
	38.22	1.71	0	76.2	6.3	5.6	18.4/20.0	0.30	3
	40.84	1.71	0	45.5	4.7	5.0	15.3/21.3	0.89	3
	40.93	1.70	0	45.5	4.7	7.6	27.5/20.0	0.80	3
	41.02	1.71	0	44.9	4.6	3.8	13.8/15.6	0.63	3
	900EB 21.55	1.71	0	88.7	5.8	1.7	22.3/25.4	0.22	2
	21.64	1.71	0	85.7	5.4	7.6	22.3/25.4	0.24	2
	21.73	1.71	0	85.0	5.1	4.6	21.7/25.4	0.27	2
	30.06	1.71	0	96.0	4.9	6.9	27.2/28.7	0.20	1
	30.14	1.71	0	108.8	4.6	1.3	30.2/30.4	0.19	1
	30.23	1.71	0	122.4	5.0	13.9	32.7/36.1	0.18	1
I	38.06	1.71	0	69.2	5.3	3.1	19.1/19.2	0.26	1
	38.14	1.71	0	66.0	4.8	1.7	19.4/20.6	0.25	2
	38.23	1.71	0	68.6	7.3	5.8	19.6/23.6	0.28	2
	40.60	1.71	0	64.3	4.7	1.3	20.4/22.0	0.20	2
	40.68	1.71	0	69.6	5.2	8.9	19.8/22.9	0.26	2
	40.77	1.72	0	66.5	6.2	1.5	21.3/22.0	0.21	1

1 No apparent bedding
2 Apparent bedding
3 Sample partly composed of sanstone-carbonaceous interlayering
  a <20% interlayering
  b >20% interlayering
p = peak
r = residual

Table 4 - Compression test results for samples from 2T1881EA

Lith. unit	Sample No.	L/D	σ_3 (MPa)	σ_1 (MPa)	ϵ_p	σ_r (MPa)	E (GPa)	ν	Remarks
	Run1 0.15	2.20	0	20.0	10.0	5.7	5.7		3
	0.30	2.23	1	51.3					2
	0.45	2.22	2	36.6					1
	0.70	2.23	3	53.5	7.0	20.3			1
	0.80	2.22	4	76.6	8.2	39.9			2
	Run3 0.05	2.20	0	19.7	7.3	6.2	4.0		2
IV (?)	0.15	2.22	1	35.3		17.6			1
	0.40	2.23	2	30.7		10.8			1
	0.55	2.22	3	69.7	6.3	26.0			1
	0.70	2.24	4	82.2	8.7	40.8			1
	0.90	2.25	5	100.6	5.8	39.6			1
	1.00	2.22	6	69.7	5.4	64.0			1
	1.05	2.24	5	65.4	6.3	38.8			1
	1.15	2.25	0	24.9	4.6		6.4		1

1 Planar failure

2 Blocky failure

3 Vertical splitting

p = peak

r = residual

Table 5 - Compression test results for samples from 2T1420A

Lith. unit	Sample No.	L/D	σ_3 (MPa)	σ_1 (MPa)	ϵ_p	σ_r (MPa)	E (GPa)	ν	Remarks
	22.61	2.25	0	45.4	10.6	4.4	6.8		2
	22.79	2.25	0	29.7	12.5	3.5	4.2		2,3
	28.51	2.25	0	61.9	12.2	3.5	8.4		1
III	28.70	2.25	0	63.6	11.5	1.5	8.0		1,3
	29.89	2.25	0	52.0	13.0	2.6	6.4		2,3
	30.00	2.25	0	67.8	12.6	2.9	7.9		2,3
	30.23	2.25	0	68.5	10.7	2.9	8.4		2
III & IV	34.0	2.25	0	24.3	7.7	2.2	4.0		1

1 Planar failure

2 Blocky failure

3 Presence of a pre-test fissile discontinuity

p = peak

r = residual

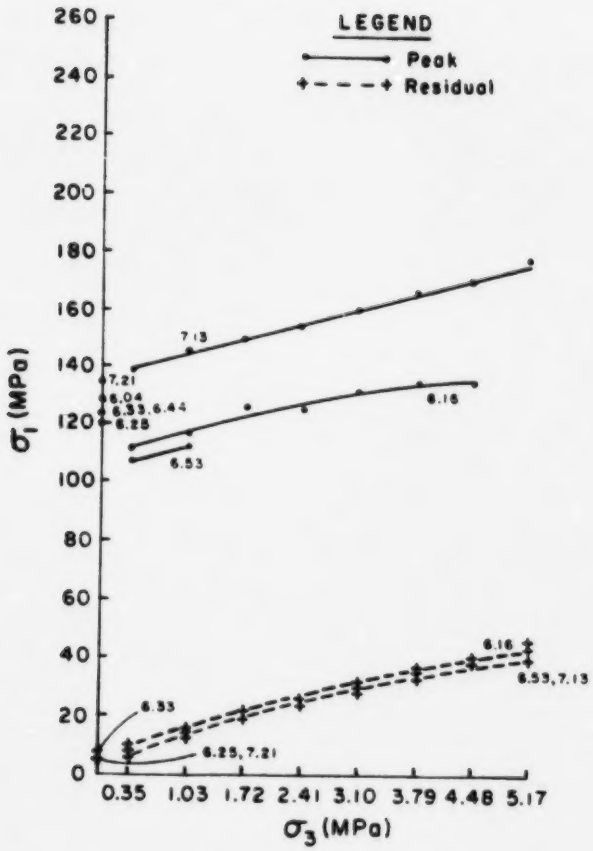

Fig. 1 - Peak and residual strength curves for specimens of Unit I EA, location 3T1025

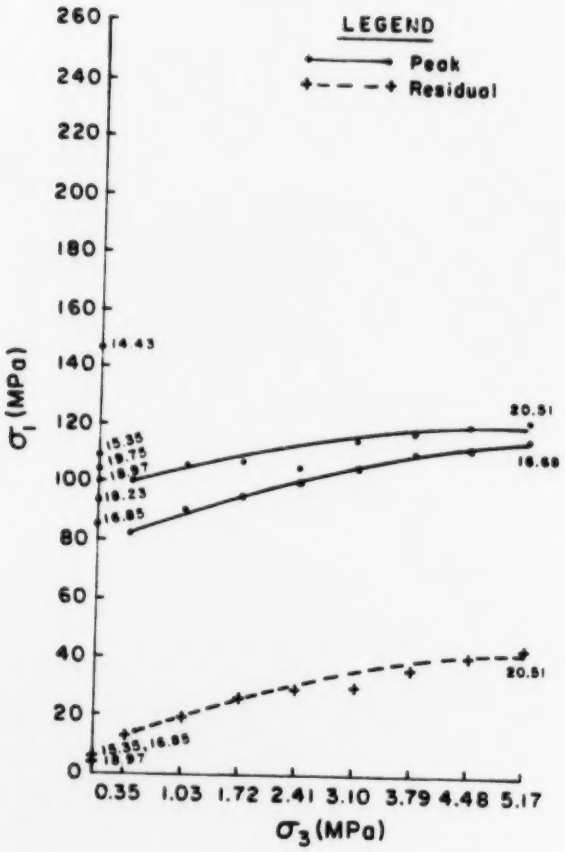

Fig. 2 - Peak and residual strength curves for specimens of Unit I ED, location 3T1025

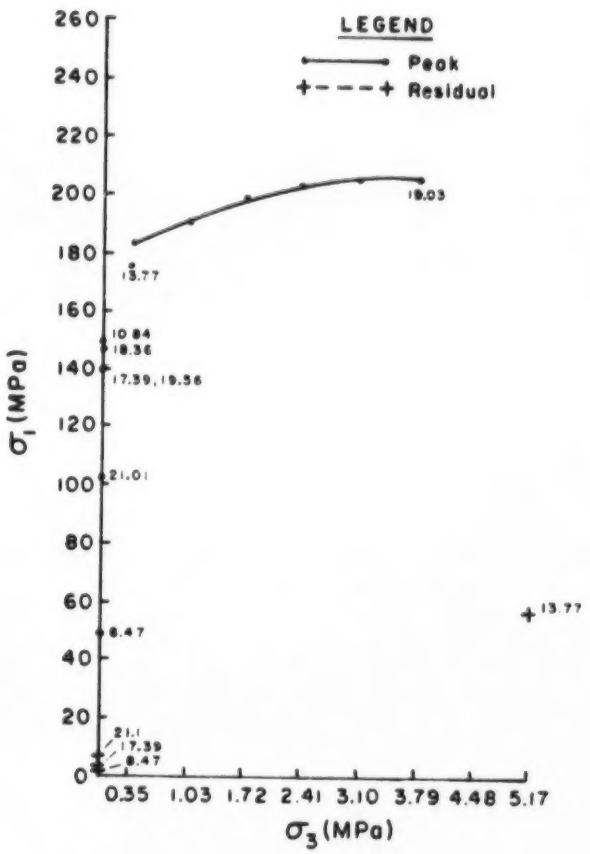

Fig. 3 - Peak and residual strength curves for specimens of Unit II EA, location 3T1025

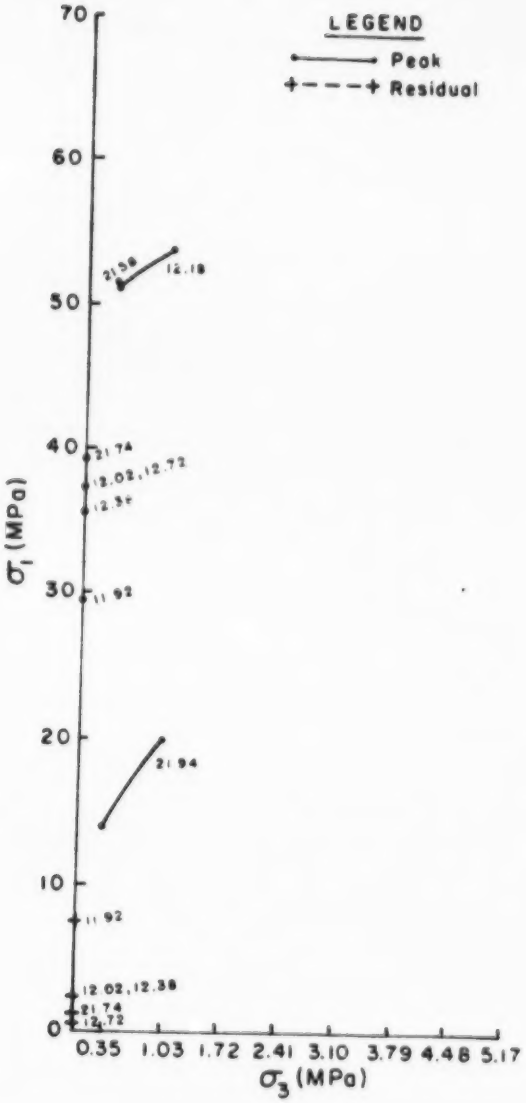

Fig. 4 - Peak and residual strength curves for specimens of Unit III EA, location 3T1025

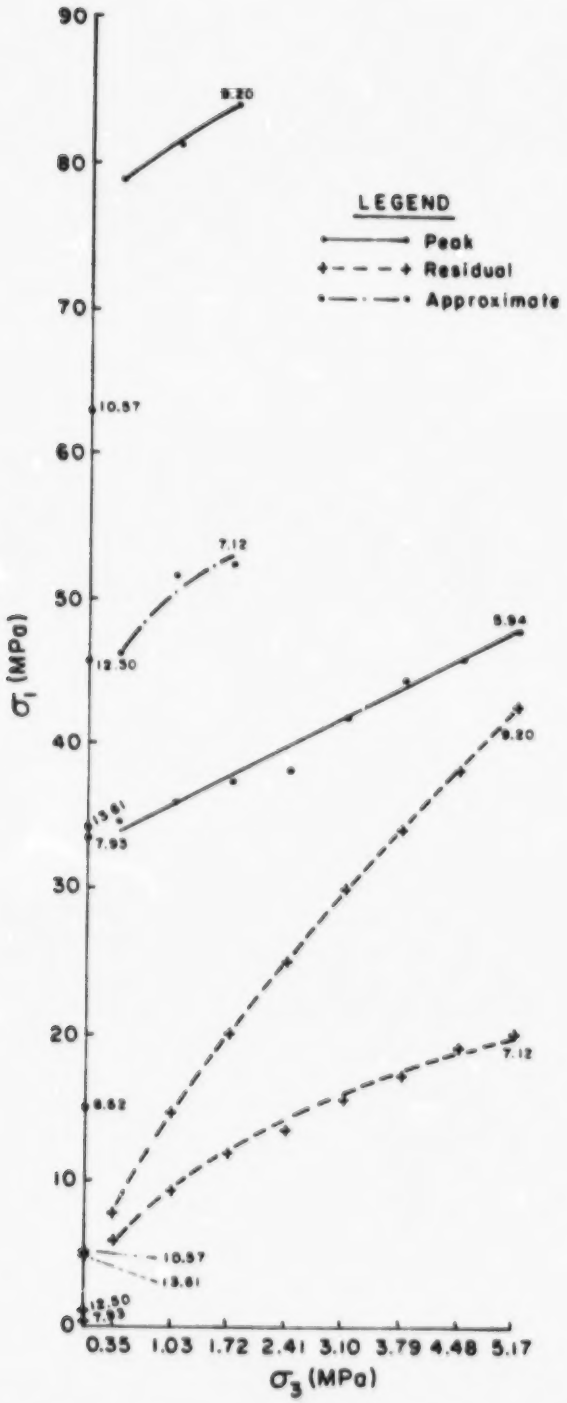

Fig. 5 - Peak and residual strength curves for specimens of Unit IV ED, location 3T1025

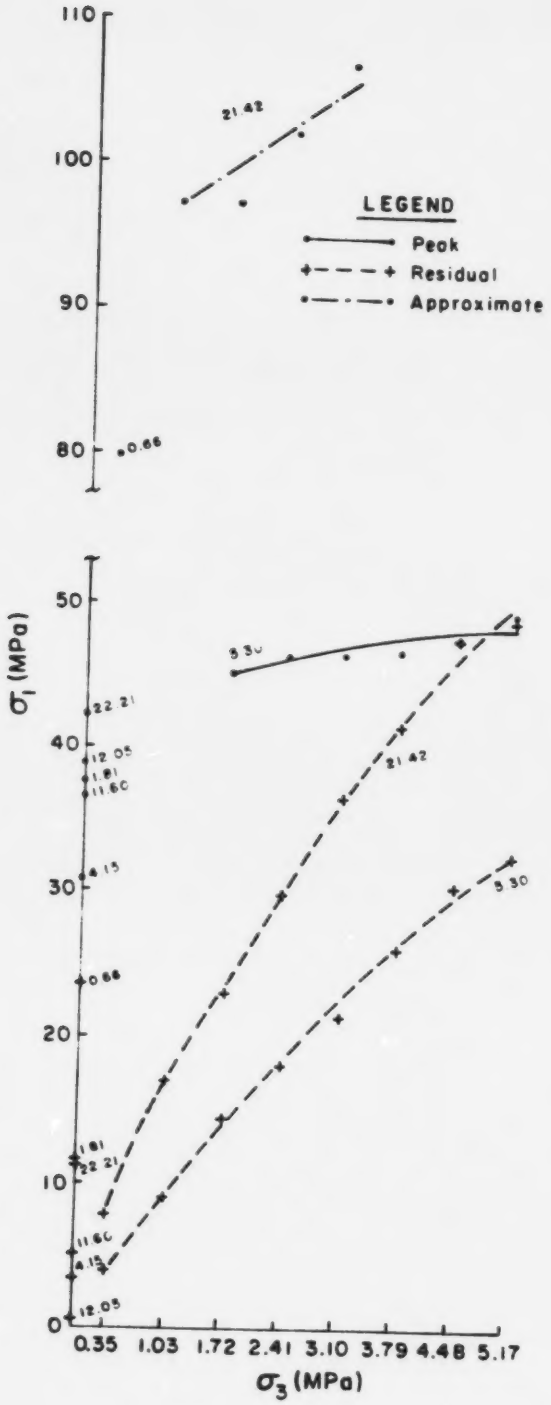

Fig. 6 - Peak and residual strength curves for specimens of Unit V ED, location 3T1025

POOR

QUALITY

ORIGINAL